INTERNATIONAL FLOWER SHOW
EXHIBIT NUMBER

BROOKLYN BOTANIC GARDEN
LEAFLETS

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THE BROOKLYN BOTANIC GARDEN EXHIBIT OF METHODS OF PLANT PROPAGATION

INTERNATIONAL FLOWER SHOW MARCH 20th-25th, 1933

This exhibit is designed to illustrate the various parts of plants available for use in propagation, and the procedures involved.

Seeds and Spores

The case of seeds shows their great variety in size and shape. Compare the enormous double coconut with the dust-like seeds of orchid, and the spherical seeds of canna with the flat, winged seeds of catalpa. Cleaned and uncleaned seeds in glass containers call attention to the desirability of removing pulpy coverings from seeds before planting them.

Seeds planted in glass jars show what happens to them when planted at various depths. Monocotyledons, (e. g. corn) and seeds in which the cotyledons remain below ground (e. g. pea) are capable of germinating at greater depths than those in which the cotyledons are raised above the surface of the soil (e. g. bean). Seeds that are planted too deeply may fail to germinate because of insufficient oxygen.

The danger of planting seeds when the soil is too wet is illustrated by seeds of peas, planted in ordinary soil and "puddled" soil on the same day. Germination is poor, or inhibited in the puddled soil.

Many seeds require stratification in moist media at low temperatures to secure best results in germination. Seeds of hawthorn, barberry, etc., are shown stratified in peat moss in a glass fronted box.

A seed flat with a glass side shows the necessary drainage material, with finely sifted soil on the surface to receive the seeds and comparatively coarse soil in between.

Seed pans with *Begonia* seeds, and fern spores, illustrate the method of handling small seeds and spores by scattering them on the surface of finely sifted, partially sterilized soil, and the maintenance of moisture about them by covering the pan with a pane of glass.

Pans and flats of seedlings of herbaceous plants and trees and shrubs are exhibited. In this group is an interesting series of seedlings

of various cacti and succulents ranging in age from a few weeks to fifteen months.

A flat of tobacco seedlings shows what is likely to happen when seeds are sown too thickly, watered too heavily, and kept in a humid atmosphere. They are suffering from "damping off," a disease caused by attacks of various fungi whose development is favored by the conditions outlined above.

Division, Tubers, Rhizomes, Bulbs

Many plants can be propagated most easily by division of the rootstock. Among the examples shown are divided and undivided plants of *Acorus gramineus, Ligularia Kaempferi, Canna* and *Dahlia.* The last should be of special interest in that it shows a portion of the stem retained on each division of the tuberous root—a necessary procedure which is often unrealized by beginners.

A flat of "greened" potato tubers shows that cuttings of subterranean tubers are used to propagate this important vegetable. Some growers prefer to use "whole" tubers.

Rooted "slips" produced by placing sweet potatoes in a hotbed illustrate the commonest method of propagating this kind of potato.

Propagation by means of stem tubers is illustrated by a flat of tubers of the "String of Hearts" (*Ceropegia Woodii*) inserted in sand. These tubers are produced at intervals on the long trailing stems.

Divided rhizomes of bearded iris are a reminder that this is a facile means of propagating this group. They may be divided in spring or fall, but most growers recommend that it be done in late summer. Cut portions of rhizomes of ferns and snake plant in flats of sandy soil serve to further illustrate this method of propagation.

Mature bulbs of various kinds tend to separate into a number of smaller bulbs which may be planted separately. Separating "mother" bulbs of tulip illustrate this. It is possible by mutilation to artificially stimulate the production of bulbils; shown here by "scooped" hyacinth bulbs. This procedure results in the formation of numerous tiny bulbils, which, when subjected to correct treatment, form flowering bulbs in from three to five years. The bulbils formed at the base of green leaf cuttings of lily and hyacinth are also shown. So far as is known, this method of propagation is not used commercially.

The leaves of some ferns produce specialized buds comparable to the bulbils of monocotyledonous plants. These are illustrated by portions of fronds of *Tectaria cicutaria* laid on sandy soil so that the bulbils may develop into plantlets.

Runners, Offsets, Layers

Many plants propagate themselves by means of *runners*—slender shoots which trail along the ground, producing at intervals buds which develop into rooted plants. Familiar examples, which are shown with the runners rooting in small pots, are: strawberry, Boston fern, and mother-of-thousands. In actual practice rooted strawberry runners are dug up from the open ground; or pots filled with earth, in which the runners are pinned until rooted, are plunged around the parent plants. Boston ferns are planted sufficiently far apart in benches of

soil so that the runners may root and form new plants, which are then dug up and potted.

Offsets are runners with short stems. They occur commonly in plants belonging in the Orpine Family and are illustrated by *Echeveria Whitei, Sedum Treleasei,* the cobweb houseleek, and others.

Layering is the term applied when branches are brought in contact with the earth or other media with a view to the production of roots. Stoloniferous shoots of *Forsythia* and *Lycium* illustrate the natural occurrence of this phenomenon, and "serpentine" and "continuous" layers of Japanese honeysuckle and rose show the artificial production of rooted plants from them. The example of "air" or "Chinese" layering should be of considerable interest to growers of house plants of the dracaena and rubber plant types. It is a valuable method of increasing plants for those who do not have normal facilities for plant propagation, and also for bringing "leggy" plants down to earth without loss of leaves.

Stem Cuttings

In the section of the exhibit devoted to stem cuttings a box with a glass front shows hardwood cuttings callused by being buried in moist peat moss (sand or sawdust may also be used). The cuttings are kept in a temperature of about 40°-45° F. over the winter. A closed propagating case shows a method of rooting cuttings of various tropical plants. Other interesting features in this section are several species that are propagated by cuttings of tuberous, aerial stems (e. g. *Kleinia, Vitis*) ; "single eye" cuttings of rubber plant, helped in rooting by grafting them on pieces of root of the same or other species; cuttings of various kinds rooted in water; and crotons rooting in inverted flower pots that are stood on a layer of wet moss in a warm, closed case.

Leaf Cuttings

Two methods are shown of raising new plants of *Begonia Rex* from its leaves. In one method entire leaves are used, which are laid flat on sand and weighted with stones. In the other the leaves are cut into triangular pieces, the proximal points of which are inserted in sand.

A flat of leaves of *Peperomia Sandersii* shows the second crop of plantlets, one crop having already been removed and potted.

In plants arising from leaf cuttings of *Sansevieria Laurentii* (the over-popular "snake plant") the yellow marginal stripe is not perpetuated. Rooted portions of striped leaves are shown with the resultant plantlets barren of stripes.

Some leaves which rapidly make roots but which do not readily form growth shoots are exemplified by croton leaves, which have had roots for the past six months but which show no signs of producing shoots.

Bryophyllum pinnatum and *Kalanchoe daigremontana* provide excellent examples of leaves which normally propagate the parent by means of plantlets produced along their margins. In the Botanic Garden last year, from a single, small plant in a three inch pot, over

eight hundred new plants of the last named species were produced by using leaf margin plantlets.

Root Cuttings

Japanese anemone, perennial phlox, *Clerodendron,* etc., provide examples of plants readily propagated from root cuttings. Roots were dug up during the winter, cut into pieces from one to two inches long, and buried a half-inch deep in flats of sand in the greenhouse.

Graftage

Because of its popular appeal, considerable space is given to a representation of this important method of plant propagation.

Examples of many of the methods of making grafts are shown mounted on a board. Of these the more important are "whip," "splice," "side," and "cleft" grafts, and "T" budding. Nearby, similarly mounted, are tools used in plant propagation.

Illustrations of the practice of producing "standards" and raising weak stemmed plants high above the ground level are seen in *Catalpa bignonioides* var. *nana* (*"Bungei"*), and crab cactus, budded or grafted on tall stocks. *Opuntia* and *Zygocactus* may be seen on a single stock of *Pereskiopsis.*

Bundles of newly grafted, and callused, apple grafts, supplied through the courtesy of the New York State Experiment Station at Geneva, serve as a reminder that practically all of our fruit trees are propagated by budding or grafting.

Lilacs are shown budded and grafted on privet cuttings. This method of propagating the lilac is condemned by many horticulturists, who claim that such lilacs are more subject to disease than those rooted from cuttings.

A propagating case is shown with newly grafted broad-leaved and coniferous evergreens. The plants to furnish this case were supplied through the courtesy of Bobbink and Atkins, Rutherford, New Jersey. We are indebted to the same firm for dormant and flowering budded roses, flowering grafted lilacs, *Rhododendron,* Japanese Maples, and some evergreens.

A section is devoted to "freak" grafts of no commercial value. Many of these grafts were made within the Potato Family and may serve, in part, to illustrate plant affinities. *Solanum sisymbriifolium* and sweet pepper, for example, look fairly happy when grafted on tomato; but potato and petunia are obviously miserable. On the other hand, petunia does reasonably well on tobacco, but tomato and potato are barely living. Multiple grafts are represented by: pepper, petunia, tobacco, tomato, and *Solanum sisymbriifolium* on one plant of potato.

Plants of *Euonymus alata,* with *E. japonica, E japonica* var. *aureo-variegata, E. japonica* var. *microphylla, E. nana,* and *E. radicans* var. *argenteo-marginata* grafted upon them provide an interesting conglomeration.

English ivy (*Hedera Helix*) grafted on devil's-walking-stick (*Aralia spinosa*) has apparently "taken." If these two genera prove to be thoroughly compatible it will open up interesting possibilities of producing "weeping" ivy plants on tall standards!

Montague Free.

INTERNATIONAL FLOWER SHOW

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XXI BROOKLYN, N. Y., APRIL 26, 1933 NO. 2-6

METHODS OF PLANT PROPAGATION

The multiplication of plants is of paramount importance to the nurseryman, and the procedures involved should be of absorbing interest to every plant lover.

Plants are propagated by means of seeds, spores, bulbils, tubers, rhizomes, division, runners, offsets, suckers, stolons, layers, cuttings, and grafting. All of these means of propagation occur in nature with the possible exception of division and grafting. Natural grafts are not an uncommon occurrence, but do not result in any apparent multiplication of the grafted plant. The natural increase of plants by means of cuttings may be questioned, but we have as example the twigs of some willows, self-pruned by means of abscission layers, which, falling to the ground, become rooted and thus propagate the parent tree. If the tree is growing on the bank of a stream it is not only multiplied, but stands a good chance of being disseminated if the twigs fall into the water and float some distance before lodging on a bank where they are able to take root.

Although plant propagation is an ancient art, it is only during comparatively recent years that scientific studies have been made in its theory and practice. The result of wide experimentation has been a remarkable increase in our knowledge of ways and means to propagate rapidly and surely plants formerly considered difficult.

SEXUAL PROPAGATION OF PLANTS

Seeds and Spores. Although horticulturally seeds and spores are much akin, botanically they are quite different. *A seed* is a ripened ovule produced in the ovary of a flower. It results from the *fertilization* of an *egg-cell* in the ovule by its union with a *sperm-cell* from a pollen-grain. When mature it contains a plant-embryo, surrounded by seed-coats. A *spore* in many cases, as in ferns, is a specialized cell, which, under suitable conditions, may germinate and form a prothallus, which, on its underside, produces antheridia (male elements) and archegonia (female elements). Spermatozoids produced in the antheridia unite with egg-cells produced in the archegonia. The result is a fertilized egg-cell (oospore). The fertilized egg-cell undergoes a process of segmentation which leads finally to the development of a spore-producing plant.

Seeds are infinite in variety of size, form, and texture. They range from the dust-like seeds of orchid and begonia to the enormous double coco-nut which is said to attain a weight of fifty pounds and dimensions of ten by twelve inches, exclusive of the husk. In form, seeds vary from the spherical shot-like seeds of *Canna* to the curious angular seeds of the Brazil nut and the winged seeds characteristic of catalpas and many of the tropical bignonias. In texture they may be soft, as in *Crinum,* whose seeds may be easily picked to pieces by the finger nail, or extremely hard as in the ivory-nut palm which is used as a substitute for ivory. The leaf forms of seedlings of some plants (e. g. some acacias, *Eucalyptus, Thuja, and Chamaecyparis*) are very different from those of mature plants. In some cases, if these seedlings are propagated vegetatively before the adult foliage is produced, the juvenile habit is retained, as in *Retinospora* varieties which are juvenile forms of *Chamaecyparis* and *Thuja.*

More flowering plants are produced from seeds than by any other means. Usually seed germination presents no problem of the gardener, provided the seeds are given their minimum requirements of air, moisture, and a sufficiently high temperature. These requirements are met, in outdoor planting, by covering the seeds with soil deep enough to keep them moist, but not so deep that they do not receive sufficient air, or so deep that the food stored in the seed is exhausted before the growing embryo reaches the surface of the soil. If the soil is heavy and sticky avoid planting when it is wet, as this may result in puddling the soil to such an extent that air is driven out and the germination of the seeds inhibited. Temperature requirements are met by starting the seeds in greenhouse, hotbed, or cold frame, or by deferring planting until the ground has warmed up sufficiently in the spring. Many of the hardy seeds may be advantageously planted in late fall; they will then germinate in early spring when the temperature is right. This affords the young plants an opportunity to develop good root systems before hot weather sets in.

But the seeds of many species require special handling, either to secure successful germination or to reduce the time between maturity and germination.

The seeds of many of our trees (e. g. oak, chestnut) will not germinate if they are allowed to become thoroughly air dried. These must either be planted as soon as they are ripe, or stored under cool conditions in a moist medium, such as peat moss, sand, or soil, previous to planting them in the spring.

Some seeds, such as willow, poplar, *Crinum,* and mangrove, are short-lived and must be planted immediately after they are ripe.

Many seeds require an "after-ripening" period at comparatively low temperatures to ensure a successful stand. It has long been known that better results are obtained with the seeds of many alpine and herbaceous plants if planted in a cold frame in the fall and the frame filled with snow as soon as it is available. The frames are then covered with insulating material, such as boards, mats, or straw, to hold the snow unmelted as long as possible. When the snow has melted, the

flats or seed pots are brought into a heated greenhouse. This procedure, as a rule, results in rapid and satisfactory germination. The Boyce Thompson Institute for Plant Research has conducted numerous experiments designed to show the most efficient methods of handling "difficult" seeds with a view to securing satisfactory germination, and has published valuable data as a result of these experiments. The ideal conditions of temperature and time of stratification to ensure the breaking of dormancy by after-ripening have been worked out for a large number of species.[3] *

Some species produce what the nurseryman calls "two year seeds" which do not germinate for a year or more after maturity. Instead of planting such seeds in the normal way they are mixed with, or stratified in, a moist medium, for a year before planting. Seeds in this group include some of the roses, hawthorns, *Cotoneaster,* and *Cornus.*

Seeds that possess hard, impervious coverings may have their germination accelerated by soaking them in hot water, by treatment with chemicals, or by filing or cracking the seed coat. The two last named methods are tedious and involve risk of injury to the embryo. Immersing the seeds in sulphuric acid for varying periods (depending on the kind of seed) is a chemical treatment sometimes used.[14] Here again, injury may result if the seeds are left in the acid too long or if they are not thoroughly washed immediately after the treatment. Pouring hot water on these hard coated seeds and allowing them to soak from 24 to 48 hours would seem to be the best general treatment. Amongst plants having seeds that belong in the above category are *Acacia, Buxus, Camellia, Canna, Gleditsia, Ipomoea,* and *Maclura.*

Until comparatively recently the raising of orchids from seeds was an extremely uncertain procedure. It was thought that the presence of a mycorrhizal fungus commonly found on the roots and potting media of orchids, was necessary for successful germination. Because of this it was a common practice to sow orchid seeds on the surface of the compost in which a similar or identical species was growing. This did not give entirely satisfactory or uniform results. Another practice followed by some growers is to plant the seeds on muslin, toweling, or burlap tightly stretched over a compost of finely divided orchid peat, charcoal, and sphagnum. About ten years ago Dr. Lewis Knudson of Cornell University[12] showed that it was possible to successfully germinate sterilized orchid seeds in flasks on a sterilized nutrient solution of agar, thus proving that the fungus was not essential to germination. This is the method used by many orchid raisers to-day. Use is also made of flasks containing a mixture of peat, sand, and agar solution which, before the seeds are sown, are sterilized and then inoculated, under aseptic conditions, with the fungus that is supposed to aid in germination.[21]

When seeds are started under glass they are subject to attacks by various "damping off" fungi. Usually, thin sowing, a porous soil, well drained pots or flats, avoidance of over watering and of too

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* The small numbers refer to the corresponding numbers in the bibliography at the end of this Leaflet.

humid an atmosphere, are sufficient to prevent these attacks. But with some seeds under some circumstances it is necessary to sterilize the soil before planting. This is done by baking or steaming; or chemically, by the use of organic mercury compounds or formaldehyde solution. It is a common practice to thoroughly soak seed pans with boiling water after they are prepared for planting and before sowing fern spores or fine seeds such as those of *Begonia, Calceolaria,* and *Gloxinia.* While this does not result in complete sterilization, it is often sufficient to enable the seeds or spores to grow successfully.

The depth of covering that is applied to seeds is quite important, for germination may be unsuccessful if the seeds are covered too deeply. In the case of small seeds the covering of soil or sand should not exceed twice their diameter, and very fine seeds should be handled by scattering them on the surface of sifted soil, made firm and smooth with a tamper, and watered thoroughly before the seeds are sown. Moisture is maintained about the seeds by covering the pan with a pane of glass which is shaded by cloth or paper until the seeds have germinated, when it must be removed to prevent etiolation (bleaching and excessive elongation due to diminished light). Sometimes, especially when dealing with *Azalea or Rhododendron* seeds, a light sprinkling of dry sphagnum moss rubbed through a fine sieve is used to keep the seeds moist.

Seeds which have fleshy coverings such as those of *Magnolia,* apple, holly, rose, *Berberis, Viburnum, Rubus,* etc., should have the pulp removed before they are planted or stratified. This is usually done by macerating them until the covering is soft and easily washed off.

Spores afford the most convenient method of propagating many of our ferns. The usual method of growing them is to sow the spores in shallow, well drained pans of fine, porous earth, previously sterilized. Some growers, before sowing the spores, cover the soil surface with brick dust or powdered flower pots, but it is difficult to discern the advantage of this practice. The pans are covered with glass and set in saucers of water. There must be no overhead watering until the prothallia are well developed. After fertilization of the egg-cells has taken place and the "sporelings" have made a leaf or two, they are pricked out in flats of light soil. It is important to harvest the fern spores at the proper time. This occurs when the sporangia are just about to open. Portions of fern leaf bearing sporangia (sporophylls) may be laid on the surface of the prepared soil allowing the spores to drift out over the nidus; or the sporophylls may be placed in paper bags until the spores are discharged, when they may be sown in the same manner as fine seeds.

Asexual, Clonal, or Vegetative Reproduction

It often happens that sexual reproduction is not desirable, either because the characters we wish to perpetuate do not "come true" from seeds or because it is more convenient to propagate the plants vegetatively. The methods adopted to bring this about are many and various.

Many of our bulbous plants propagate naturally by the bulbs dividing into smaller bulbs or bulbils which may be planted separately to form new flowering bulbs. The tulip, for example, when it has attained maximum size (known as a "mother" bulb), tends to split up into a number of smaller bulbs. In some cases the tendency to form bulbils may be accelerated by mutilation of the bulbs. This is the usual practice followed in the asexual propagation of the hyacinth. Either deep vertical cuts are made through the base of the bulb (scoring), or the base of the bulb is removed (scooping), exposing the bases of the scale leaves which form the bulbs. This is done in the summer. Before planting time in the fall numerous small bulbils form along the cut surfaces. These are planted still attached to the mother bulb and make mature bulbs in from three to five years.[6]

Scaly bulbs such as those of lilies may be propagated readily by removing the outer scales and planting them in the same way that one would plant seeds—although they are really scale-leaf cuttings. Incidentally, it may be news to some people that normal hyacinth and lily leaves may be inserted as cuttings, resulting in the formation of small bulbils.

Corms, popularly classed as bulbs, are bulb-like structures, but are solid throughout instead of being formed of scale leaves as in true bulbs. They increase in much the same way as bulbs by one or more corms being formed on top of the old corm. In addition, as in *Gladiolus,* a number of tiny corms, known as *cormels,* may be produced around the base of the new corm. Cormels may be treated in essentially the same way as seeds.

Bulbils are formed on the aerial parts of several genera. Examples are the small bulbs formed in the leaf-axils of several species of lilies, or those formed in the inflorescences of "top" or "multiplier" onions. The bulb-like, propagative organs found on the leaves of several ferns, as in *Tectaria cicutaria, Asplenium bulbiferum,* and *Camptosorus rhizophyllus,* may be included here.

There are *root tubers* and *stem tubers.* The latter may be subterranean or aerial. Familiar examples of subterranean tubers are potato and Jerusalem artichoke. Aerial tubers are found on some species of *Dioscorea, Kleinia,* and on *Ceropegia Woodii,* also, as freaks, on the potato. One of the grape vines (*Vitis gongylodes*) produces swellings of its stem comparable to tubers. Tubers afford a ready means of propagating plants that produce them, either planted whole or cut into portions, each possessing a growth "eye." The *Dahlia* is an example of a tuberous root. When dahlias are divided for propagating purposes it is necessary to cut them with a portion of stem attached to each root.

Rhizomes are underground, or partially underground, stems, which if cut into portions, each bearing a growth bud, allow for rapid increase of plants producing them. Usually these divisions are made when the plants are dormant, but in the case of rhizomatous iris many

growers prefer to do this immediately after the plant has flowered. The demarcation between subterranean tubers, rhizomes, and runners is not well defined. The tubers of *Helianthus tuberosus* approach rather closely to some rhizomes; and the root-stock, or stool, of *Canna*, which may be regarded as a mass of short, stocky rhizomes, is very much like some tubers. The rhizomes of some ferns (e. g., *Davallia*) run along the surface, and it is difficult to mark any real difference between them and the trailing growths of such plants as *Nepeta glechoma* to which the term *runner* is applied.

Division

The methods of vegetative propagation just described may in some respects be considered as division. The term is more generally applicable, however, to rootstocks that have to be forcibly separated by hand or by tools into pieces capable of propagation. Division is used as a means of propagation mainly with herbaceous plants, although it can be adopted successfully with shrubs such as some spiraeas, roses, hydrangeas, etc. In England it is practically the only means employed to increase the stock of the dwarf boxwood used for edging.

The operation is usually carried out when the plants are dormant, and, in the case of hardy plants, when the soil is workable. As previously mentioned, rhizomatous irises are commonly divided soon after they have finished flowering, or in August; peonies in early fall. The size of the divisions is dependent on the type of plant, quantity of stock available, and purpose for which they are required. They may consist of single "eyes", "crowns", or buds, or several may be contained in each division. Division is often accomplished by chopping the clump or rootstock into pieces of the desired size by means of a spade or mattock. This, however, is a "brutal" and destructive method and, as a rule, better results are obtained by thrusting two spading forks (or hand forks if the plant is small) into the clump and prying it apart.

Runners, Offsets, Suckers, Slips

Many plants give off specialized shoots which serve for the purpose of vegetative reproduction. *Runners* are slender shoots that run along the surface of the ground, at intervals forming buds from the base of which roots are produced. An example is the strawberry, which is propagated almost entirely by runners. Sometimes the rooted runners are dug from the open ground. Sometimes the gardener plunges flower pots filled with earth about the parent plants and pins the runners in them, so that when rooted the young plants may be transplanted without root disturbance. *Offsets* are similar to runners but have shorter stems. The houseleek is an example of a plant producing offsets. In some species of houseleek, as in *Sempervivum globiferum*, the offsets are comparable to bulbils produced by some monocotyledonous plants. They are formed in the axils of the leaves, fall off when mature, and, if growing on a slope, roll away to form new colonies. Offsets may be taken from the parent plant any time

when they are mature; planted in pots or flats of sandy soil they will grow without any special treatment.

Suckers are branches given off below the surface of the soil which grow erect and produce roots, as in the lilac and plum. Suckers may be dug up with roots attached in either spring or fall. When using this method of propagation it is necessary to be certain that the tree or shrub you wish to increase is not grafted on a different variety. The formation of suckers may be artificially stimulated in some subjects by root mutilation. This may be seen in the crop of suckers that arises when the roots of such trees as Lombardy poplars have been injured by spade or fork when working around them.

The terms "offset" and "sucker" are sometimes applied to the side shoots arising from *Pandanus,* pineapple, and similar plants. In the pineapple these shoots are also called "slips"; this term is popularly applied to shoots of any plant that are pulled, or slipped off, and used as cuttings. The rooted shoots of sweet potato, produced by placing the tuberous roots in hotbeds and covering them with sand, are called "slips". These with attached roots are pulled from the mother root when they have attained a length of six inches. This is the accepted method of propagation of sweet potatoes, rather than by tubers as in the case of "Irish" potatoes.

It will be noticed that the terminology used in describing the various portions of plants used in propagation is far from exact. This is not surprising when it is remembered that a tuber may be but a much thickened rhizome, an offset an abbreviated runner, and that the pineapple produces true suckers which are practically indistinguishable from its aerial side shoots.

Stolons and Layers

A *stolon* is a branch given off above the soil level which, either by growing downwards or of its own weight, comes in contact with the soil and takes root. Shrubby plants that naturally take root in this way are fairly common. Examples that come to mind are: *Forsythia,* matrimony vine, several shrubby species of *Cornus,* raspberry, dewberry, and many willows. Stolons, when rooted, may be severed from their parent and transplanted to lead an independent existence.

The term *layer* is applied to a shoot wholly or in part covered with earth to promote the formation of roots. Layering, on the whole, is a sure method of plant propagation, and does not demand much in the way of skill or equipment. In some cases, however, it is not so prolific as seeds, cuttings, or grafting. It may be successfully used with most woody plants that possess a habit of growth which enables their branches to be brought in contact with the ground. If the part covered with earth is notched or slit it favors the production of roots. As a general rule layers should be made in the spring. They will be rooted and may be severed from the parent plant in the fall and transplanted the following spring. With some plants (e. g. Japanese honeysuckle) layers will root and be ready for transplanting in less time than this; others (some rhododendrons and magnolias) may take longer.

When plants form long, flexible shoots, as in grape vines and some roses, several rooted plants may be obtained from one shoot by using serpentine or continuous layering. By the former method the shoot is undulated and the lower loops covered with earth or buried in shallow trenches. In continuous layering the shoot is pegged down and covered lightly with earth throughout its length.

Mound layering is a convenient way of increasing plants of bushy habit. The stock plant is cut back a year before it is to be layered. This is done to promote the production of quantities of shoots near the ground. The following spring it is "layered" by making a mound of earth over the center of the bush thus covering the bases of the shoots. In a year these shoots will be sizeable plants well furnished with roots.

Air layering (or Chinese layering) is applicable to trees or shrubs whose branches cannot conveniently be brought in contact with the ground. A notch is cut in the branch, or the bark is girdled, at the point where root formation is desired—usually one to two feet from the tip. A hinged layering pot of metal, or one of pottery, slotted on one side to the drainage hole, is then placed on the branch over the wound. The branch passes through the hole in the bottom of the pot. The pot is then filled with soil which is kept moist until sufficient roots are formed, when the rooted branch is severed and planted as a separate plant. Layering pots may be improvised by breaking ordinary flower pots into approximately equal "halves" and tying the broken portions together about the branch. You *may* be able to get the pot to break just right at the first attempt, but the chances are that two or three dozen pots will be ruined before one breaks to your liking! Another method would be to form a cone of water proof paper, thin sheet zinc, or rubber sheeting, about the branch to hold the soil. Under greenhouse conditions, where humid conditions may be maintained, air layering is usually accomplished by wrapping the wound with a double handful of sphagnum moss, which is tied in place and kept moist by the spraying that the plants normally receive.

Air layering is a valuable means of propagating plants that are not easily or conveniently increased by other methods. It also offers a practical method of "bringing down to earth," without loss of leaves, "leggy" plants with bare stems and leafy tops. It is commonly applied to dracaenas of the "feather duster" type. Apartment house dwellers whose dracaenas are touching the ceiling may use air layering to advantage.

Cuttings

The term cutting is applied to a portion of a plant severed from its parent and treated with the object that it may form roots and produce a new plant.

Cuttings may be made of stems, leaves, portions of leaves, tubers (Potato), fruits (*Opuntia*), and roots.

Stem cuttings are made of growing shoots (softwood cuttings) or of dormant shoots (hardwood cuttings). Softwood cuttings of

herbaceous plants (e. g. *Chrysanthemum, Phlox,* and *Delphinium*) are inserted in early spring, or at any time during the growing season when young shoots about three inches long are obtainable. It is believed that if the cut can be made below the surface of the ground the cutting will root more easily. Softwood cuttings of woody plants are made between May and July. An important factor in success with cuttings of growing shoots is the maintenance of a humid atmosphere about them. This is accomplished by placing them in greenhouses, propagating frames, under handlights, bell jars, or even preserving jars, and by shading and spraying as often as necessary to keep them turgid. In preparing the cuttings for insertion, no more leaves should be removed than is necessary to prevent wilting. Usually the lower leaves of the cuttings are removed to facilitate insertion, but L. B. Stewart, of the Royal Botanic Garden, Edinburgh, says, "The removal of leaves from the stems of cuttings is a practice to be condemned, as a great deal of time is wasted in cutting off the leaves; the cutting itself generally sheds them if they are not required."[18]

Practices followed in propagating some monocotyledons, such as *Dracaena* and sugar cane, involve the use of both "hard" and "soft" wood. In the case of *Dracaena* the dormant canes are laid horizontally in propagating beds where a temperature of between seventy and eighty degrees Fahrenheit is maintained. The canes are covered with about an inch of sand, sand and peat moss, or sphagnum moss. This procedure results in the production of young shoots from dormant buds along the whole length of the cane. These shoots, when large enough, are taken off and inserted as softwood cuttings.

The position on the stem of the basal cut is important. Older recommendations were to make the cut just below a node, or to take the cuttings with a "heel" of older wood. In tests made by Chadwick with softwood cuttings of trees and shrubs, comparison was made of the results of the cut made at the node, about one half-inch above the node, and about one-half inch below the node. "Of the eighty-six plants listed, five seem to have rooted best when the cut was made above the node, seventeen when the cut was made at the node in the usual way, forty-one when the cut was made below the node, and twenty-three seem to be indifferent to at least two of the three cuts."[13]

The media used for the insertion of the cuttings has an important bearing on the results obtained. The commonest medium at the present time is clean, rather coarse sand. However, tests made by recent experimenters tend to show that while sand is the best medium for some varieties, a half and half mixture by bulk of peat moss and sand gave best results with the majority of the plants tested, while peat proved to be the best medium for a few kinds. Slag has been used successfully with some varieties.

Coco-nut fibre refuse is sometimes used with good results in European practice and many old-time gardeners prefer a porous soil mixture, surfaced with sand, in which to insert the cuttings. Some cuttings root readily in water (e. g., *Luculia,* oleander, willow), and

for some tropical plants (*Nepenthes*, etc.) the practice of inserting the cutting through the drainage hole of a small flower pot inverted over a layer of moist sphagnum moss is effective.

It is desirable to maintain the rooting medium at a higher temperature (5° F. to 10° F.) than the air surrounding the cuttings in order to stimulate root action before top growth starts. This is accomplished by heating pipes, fermenting manure or leaves, or by electric heating cables beneath the cutting bed.

More than twenty-five years ago the writer, in England, had considerable success in rooting difficult plants in a sun frame, or "French" frame. This consisted of an ordinary cold frame with four inches of porous soil surfaced with two inches of sand. It was installed in full sun, the sash put on with no ventilation, and no shade provided. On sunny days the cuttings were sprinkled with water about every half-hour. A modification of this system is described in U. S. Dept. of Agric. Department Circular 310, May, 1924, "The Solar Propagating Frame for Rooting Citrus and other Sub-tropical Plants." The purpose is to provide bottom heat by sunshine.[19]

Many investigators, both abroad and at home, have successfully used chemicals to accelerate the rooting of cuttings, either by soaking the cuttings in the solution or by applying the solution to the rooting medium. According to Laurie and Chadwick, "The two that have given most promise as stimulants are potassium permanganate ($K\,Mn\,O_4$) and sucrose ($C_{12}\,H_{24}\,O_{11}$)."[13] (The best results with potassium permanganate were obtained with a solution of [illegible]lbs. of $K\,Mn\,O_4$ to fifteen gallons of water—two quarts applied to each square foot of rooting medium.)

Some plants that are difficult to root from cuttings may be successfully handled if the cutting wood is obtained from plants forced in the greenhouse. Examples are *Acer, Chionanthus,* and *Daphne Cneorum*.

The etiolation of the stem by "taping," or otherwise, at the point where the basal cut is to be made may facilitate root formation. Promising results were obtained at the Maryland Agricultural Experiment Station with taped (and, in some cases, girdled) cuttings, of several varieties of apples, planted in late summer and early fall.[5] E. Philip Smith found that stem cuttings of *Clematis,* which ordinarily do not root at the node, may be made to do so by etiolating the stem at the node before making the cuttings.[17] L. B. Stewart states that, "In the propagation of Camphor, or any plants which contain alkaloids, oils, or anthocyanin, the propagator is up against a difficulty. Where a large proportion of camphor is present in the stem it will be found that this plant is more difficult than many of its "brothers" with a less percentage. It is, therefore, necessary in these stubborn cases to etiolate the stem anything from 16 to 20 days."[18] F. E. Gardner, of the Maryland Experiment Station, gives some interesting data bearing on the relation that the age of the tree from which cuttings are obtained has to their rooting response. For example: Cuttings taken from arborvitae two years old rooted 100%,

while only 42% of the cuttings rooted that were taken from an old arborvitae.[5]

Dormant or Hardwood Cuttings—Evergreens

There are all stages of transition between honest-to-goodness softwood cuttings and hardwood cuttings. Many deciduous and evergreen plants root with facility from cuttings made from what the gardener calls half ripened wood. At the Maryland Experiment Station cuttings of American holly taken on nineteen occasions between June 19th and April 6th of the following year gave best results between August 20th and the end of September. Of those planted on September 9th 100% rooted, and of those planted on September 22nd 98% rooted. The percentage rooting dropped to 46% of the November 15th insertions and rose to 84% of the insertions of November 29.[5]

Cuttings of coniferous evergreens of quick-rooting kinds, such as some varieties of *Retinospora* and *Thuja,* may be inserted during August in propagating frames out-of-doors, and left there until the following spring if carefully protected from winter injury. The more usual practice, however, is to root the cuttings under greenhouse conditions (at about 60° F.) from material of the current season taken between October and the end of the year. If possible, the cuttings should be gathered when they are not frozen. The kind of media used has a great influence on the rooting of some coniferous evergreens. Tests made by Chadwick with several varieties of *Taxus,* for example, indicated that a mixture of peat and sand was not the ideal rooting medium. With few exceptions the greatest root development (length and number of roots) took place in peat, and, on the whole, sand gave better results than the mixture of sand and peat. There is also a relation between the time when the cuttings are taken and their success in peat or sand media. "Cuttings taken early in the fall root much better in peat than in sand. Cuttings taken in December and February show the highest percentage of rooting in sand, the difference increasing as the cuttings are taken later and later in the winter."[13]

Convenience may dictate whether the cuttings are placed in flats or benches. The air about the cuttings should be humid and they need protection from strong sunshine.

Hardwood Cuttings—Deciduous

Cuttings of dormant wood afford an easy means of propagating many shrubs and some trees. The cuttings are made of firm wood of the current season, after the leaves have fallen, and are cut into lengths of six to ten inches. Some shrubs, such as *Diervilla* and *Althaea,* are what the nurseryman calls "end growers," and of these only the tips of the shoots should be used. When the cuttings are made they are tied in bundles of fifty or a hundred, with the butts even and pointing in one direction. They are then packed in moist sand, peat moss, or sawdust and stored in a cool cellar (40°-45° F.) over the winter. If a

suitable storage structure is not available they may be buried out-of-doors in sandy, thoroughly drained soil. By the time the ground is workable in the spring the cuttings are callused and ready for planting in nursery rows. The usual practice is to set them deeply with only the tips showing above the surface.

Leaf Cuttings

Although the leaves of many varieties of plants will root, if inserted in suitable media and properly cared for, the number of plants commercially propagated by this means is not large. Succulent plants such as *Sedum, Echeveria,* some species of *Kalanchoe,* and *Bryophyllum* readily produce plantlets from leaves inserted in sandy soil and this method offers a convenient way to propagate them. In the case of the first two named, mature leaves are pulled from the parent plant and the stem end pressed into loose sandy soil. They root readily without any special treatment and the young plants are produced from buds originating at the bases of the leaves. In *Bryophyllum* and *Kalanchoe* the leaf is laid flat on the surface of sand or sandy soil and weighted down with stones. The young plantlets are produced in the indentations along the margins of the leaves. These plantlets may grow and produce roots while still attached to the parent plant without benefit of being placed on moist soil or sand.

Several kinds of *Begonia* are habitually propagated from leaf cuttings. In *Begonia Rex* the entire leaf may be laid flat on the rooting medium and pinned down with hairpins (if obtainable), or weighted with stones. When this method is followed the usual practice is to cut through the main veins just below the point where they fork. Another method is to cut the leaf into V-shaped pieces each containing a good-sized vein. These are inserted in sand, with the proximal point of the "V" down, in a warm propagating case. Begonias of the "Gloire de Lorraine" group may be increased by taking entire leaves and inserting the petiole in the rooting medium. The same method is followed with *Peperomia, Gloxinia,* and *Saintpaulia.*

Sansevierias may be propagated by cutting the leaves into lengths of about three to five inches and inserting them (right end up, of course) in sand. The statement has been made that *Sansevieria Laurentii* will not produce plants by this method. This is not so. It will produce new plants, but apparently they do not have the yellow stripe along the margin of the leaves that is characteristic of *S. Laurentii.*

There are many plants whose leaves will emit roots but which do not readily produce growth shoots. *Codiaeum* and *Dendromecon* come to mind as examples.

Root Cuttings

Many plants, both herbaceous and woody, may be propagated with ease by means of root cuttings. If greenhouse facilities are available the roots may be dug in early winter, cut into lengths of one to three inches, and buried one-half to one inch deep in flats of sand, or sand

and peat. The thickness of the roots used is dependent on the subject—varying from 1/10 of an inch in the case of Phlox to ½ inch or even more with some of the woody plants. Cuttings of the roots of hardy plants may be taken in the fall, stored in a cool place in moist peat or sand, and planted out-of-doors in the spring, or they may be made in the spring and planted immediately. The former procedure is to be preferred. Plants commonly propagated this way are: Japanese anemones, *Verbascum* (named hybrids), *Phlox, Aesculus parviflora, Clerodendron trichotomum,* and *Sophora.*

Budding and Grafting, or Graftage

These are the terms used to describe the operation of placing, or inserting, a portion of one plant (bud or scion) upon another plant (the stock) to unite them so that the scion is supported on the roots of the stock.

The reasons for adopting this procedure with certain plants, or groups of plants, are many. In some cases graftage is used to propagate plants which, because of their mixed ancestry, do not "come true" from seeds, or which do not readily root from cuttings. Most of our fruit trees come in this group. Apples are budded or grafted on seedling apples, or grafted on pieces of root of older trees. Peaches are usually budded on seedlings of the "wild" peach; pears are budded on pear seedlings, or on quince stocks obtained from cuttings or layers, and so on.

Sometimes graftage is employed to modify the growth of the scion, as when apples are worked on Paradise stock, and pears on quince stock, for the purpose of dwarfing them. Seedlings may be grafted on an old stock for the purpose of hastening their flowering or fruiting. Graftage may be employed when a plant does not make satisfactory growth on its own roots. For example, most of the Tea and Hybrid Tea roses are budded on stocks having a strong root system, and it is a common practice among nurserymen to bud or graft named lilacs on plants or cuttings of privet. This latter practice has been roundly condemned by some horticulturists who claim that lilacs should be raised from cuttings. It does, however, result in a salable plant in a shorter time, and, if grafted low down and subsequently planted deeply, so that ultimately the lilac may form its own root system, it is difficult to see any objection to the practice. In any case it is preferable to working named lilacs on seedling lilacs which are likely to sucker badly and choke out the scion.

Grafting and budding are also used when it is desired to produce a plant of special form, as when "weeping" trees (mulberry, *Sophora*, elm, etc.) are worked on a tall stock. Standard or "tree" roses, and "umbrella" catalpas are similarly produced.

Plants of trailing or weak habit of growth may be grafted on sturdy stocks so that their charms may be more effectively displayed. Crab cactus is often grafted on *Pereskia,* and trailing forms of *Cereus* upon upright-growing kinds.

It is difficult, and perhaps impossible, to define the limits within which grafting is possible. Although it is reported that successful unions have been made between plants in such distantly related families as Chicoreaceae and Euphorbiaceae, as a general rule, there must be a close affinity between stock and scion to ensure a successful union.

There is much variety in the technique employed in budding and grafting. Limitations of space necessitate that only the more important be mentioned here.

In budding, a single bud, with bark (and sometimes a portion of wood) attached, is inserted under the bark of the stock, usually when the cambium layer is active. The technique commonly followed is that known as T (from the shape of the cut in the stock), or *shield budding* (from the shape of the portion inserted). It is usually performed during the summer when the bark separates readily from the wood. Roses, apples, and peaches are amongst the plants propagated in this way. After the bud is inserted it is tied in place with raffia, waxed cloth strips, or woollen or other soft string. Rubber budding strips are coming into use for holding buds in place and are favorably reported upon. If non-elastic material is used for tying the buds, the ligatures must be cut ten days or two weeks after the bud is inserted, to prevent strangulation of the bud by the tightening of the tie, brought about by increase in diameter of the stock. Budding is usually performed on seedlings one to three years old, but, in the case of roses, the practice is sometimes followed of inserting buds at intervals along the whole length of strong canes of older plants. These canes, after a few days, are then cut into sections and treated as cuttings, or they may be layered. Lilacs may be successfully budded on unrooted cuttings of privet which are then inserted in suitable media for rooting.

Patch budding is the method often employed when the plants to be operated on have thick bark, as in some nut trees. A rectangular piece of bark is removed from the stock, and a piece of exactly the same size, containing a bud of the variety it is wished to propagate, is fitted into the depression and tied snugly in place with strips of waxed cloth. A double bladed knife with the blades set parallel, about one inch apart, or a tool with four blades set in a rectangle about 1" x ½" is often used to facilitate patch budding. *Flute, annular* and *whistle budding* are variants of patch budding. *Plate,* and *H budding* are variants of shield budding. In *chip budding* a mortise is cut in the stock and a chip of bark and wood containing a single bud is cut to fit the hole thus made. *Prong budding* is perhaps more nearly akin to scion grafting, in that a small twig is attached to the shield-shaped portion that is slipped under the T cut of the stock.

Grafting

Grafting is the application or insertion of a shoot (the scion), usually not more than one year old and containing one or more buds, to or into the stock. Union takes place in the cambial tissue, which

is between the bark and the wood. This must be remembered when the stock and scion are of unequal size, and the scion so placed that, on one side at least, its cambium is in contact with that of the stock. Scion grafting is usually done in winter or early spring, when the scions are dormant.

The simplest form of grafting is the *splice graft* commonly used in "working" roses intended for greenhouse forcing. A sloping cut is made in the stock and a similar one in the scion. The cut surfaces are placed together and tied. They are then placed in a close grafting case until united.

Whip grafting is the method frequently used when working on "whole" or "piece" roots. Long sloping cuts are made on both stock and scion. Tongues are made on both stock and scion by vertical cuts starting near the point of the diagonal cuts. Stock and scion are then fitted together and tied with waxed string. The finished grafts are tied in bundles and handled in the same way as hardwood cuttings. This type of grafting is done in the winter. Millions of apple trees are propagated this way every year. When a large number of grafts are to be made machines are used to facilitate tying.

The *side graft* is used a great deal in the propagation of evergreens and Japanese maples. The stocks used are seedlings or cuttings, two or three years old, with stems about the thickness of a lead pencil. They are potted in the spring so that they may be thoroughly established before they are brought into a cool greenhouse in the fall. Three or four weeks before grafting is to start they are placed in a warm house (60° F.-65° F.) to induce new root formation. When the roots are actively growing the stocks may be grafted. A slanting cut is made, one to two and a half inches long, extending almost to the center of the stock. The end of the scion is cut to a long wedge shape and fitted in the cut on the stock with the cambium layers together. The scions are tied in place with twine or rubber strips. The pots are then plunged, almost horizontally, in peat moss, sand, or sphagnum, with the scion uppermost. Usually they are kept in propagating cases in the greenhouse. In about four weeks the stock and scion should be united, at which time less humidity is maintained about them, and about one-third of the top of the stock is removed. In another four or five weeks the remainder of the stock may be removed, or, in the case of difficult subjects, another third, leaving the remainder to a later date.

The *veneer graft* is a modification of the side graft. A piece of bark and wood is removed from the stock by a long diagonal cut (about 2 inches) and a shorter almost horizontal cut. The scion is cut to fit. The advantage of these types of graft over splice, whip, saddle, or wedge graft is that if union fails to take place the stock is still available for the insertion of another scion.

The grafting of coniferous and broad leaved evergreens, Japanese maples, magnolias, tree peonies (these are usually worked on "piece" roots of herbaceous peonies) etc. is usually carried out under glass during the first three months of the year.

Cleft grafting is the method largely used in making over old fruit trees to new varieties. The scions are cut wedge shaped and inserted in a branch, preferably not more than two inches in diameter. The stock is cut off squarely and a cleft made with a grafting chisel in which the scions are placed with their cambium layers in contact with those of the stock. All exposed cut surfaces are then waxed. This work is done in the spring when growth is starting. In all grafting work it is desirable that the stock be in a slightly more advanced stage of growth than the scion. In outdoor grafting the scions may be held back by cutting them during the winter and storing them in a moist medium in cold storage, or by burying them in a cold, shaded spot out-of-doors. In outdoor grafting all cut surfaces are covered with grafting wax. In some cases (nut grafting) the entire scion as well as cut surfaces may be coated with melted paraffin wax.

Grafting by Approach, or Inarching

This practice is adopted when dealing with plants that are difficult to propagate or graft by the usual methods, or when it is desired to work a seedling on an older plant in order to hasten its flowering. In the first case the stocks are grown in small pots. They are then brought near the twigs that are to serve as scions, either by tying them to the branches of the plant to be propagated, by fastening them to a stake, or by standing them on a conveniently situated shelf or platform. A sliver of bark is removed from both stock and scion, the cut surfaces brought together, and tied. In this method of grafting the scion is not removed from the parent plant until it has united with the stock. When approach grafting is used for the purpose of hastening the flowering of seedlings the same procedure is followed, but in reverse, inasmuch as the seedlings (scions) are in small pots.

The foregoing is merely a summary of the practices followed in plant propagation. It has not been possible to go fully into details. Enough has been written, however, to indicate that the all-round plant propagator is expected to know quite a lot. It should be understood that in many cases even varietal difference in plants demand a modification of the procedure that may be successfully applied to the species.

For the benefit of those who wish to delve further into this fascinating subject a short bibliography is appended.

Montague Free.

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BROOKLYN BOTANIC GARDEN

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HAY FEVER—A STUDY IN APPLIED BOTANY

Hay Fever is a disease characterized by an irritation and congestion of the mucous membranes which line the eyes, nose, palate, throat, and bronchi (the tubes of the lungs). The chief signs and symptoms are redness, burning, itching, tears, and swelling of the eyes; sneezing, congestion and running at the nose; itching and burning of the roof of the mouth and throat; coughing and asthmatic attacks (the last in about 60 per cent of those afflicted). In some cases the tube which connects the inner ear with the throat (the Eustachian tube) is affected, causing intense itching and burning within the head, and in another small percentage the skin is affected somewhat as in eczema. To these local symptoms are frequently added a degree of general indisposition, considerable languor, loss of appetite, an incapacity for muscular exertion, restless nights, and loss of weight.

The name Hay Fever is a misnomer, because the malady is neither caused by hay, nor is it associated with any fever. Though not a new disease, it was first recognized as a definite ailment only in 1819. In that year, Dr. John Bostock of London wrote a detailed description of his own case, he having been a sufferer for 38 years (i. e. from his eighth year). Nine years later (1828) he wrote another account of the malady (describing 28 other cases) in which the term Hay Fever appears for the first time. "Since the attention of the public has been turned to the subject," said Bostock, "an idea has very generally prevailed, that it is produced by the effluvium of new hay, and it has hence obtained the popular name of the hay-fever." And it has been called hay fever ever since.

The chief characteristics of hay fever, which distinguish it from any other ailment are:

1. Itching and burning sensations of the eyes, nose, mouth, and throat.

2. Sneezing, which is paroxysmal, that is, occurring in volleys of five to twenty and more.

3. Periodicity; it recurs year after year at the same season.

4. Duration; it lasts from 5 to 8 weeks depending on the type.

5. There are 3 well-defined seasons: spring; late spring and summer; late summer and autmn. One person may suffer from only the

spring type, another from only the summer type, etc. Some, however, suffer from all three types.

6. The influence of heredity. Of a thousand hay fever subjects about 600 will have blood relatives who have hay fever or some allied ailment; while a thousand normal individuals will have only about 70 relatives so affected.

7. Variation of intensity of symptoms, which is definitely influenced by the amount of sunshine, rain, temperature, velocity and directness of the wind, humidity, etc. Patients suffer much more on warm, bright, sunny days, especially if windy, and decidedly less on rainy days.

8. The termination of any hay fever season is often quite abrupt, it frequently being a matter of only a few hours between a condition of rather intense suffering and one of more or less complete freedom from symptoms.

9. The absence of any permanent changes in the organs affected. It is really surprising that so many persons suffer so severely from hay fever year after year without any resulting permanent after-effects. Within a short period from the termination of a hay fever season there is practically no evidence of the malady. There is one important exception, however, and that is the asthma which is frequently associated with the ailment. If not adequately treated, this form of asthma increases in severity each hay fever season, until the subject is afflicted with it throughout the year.

What is the cause of this strange ailment? Hay fever is caused by the pollen of plants—a fact which explains most of the characteristics of the malady which are mentioned above. For example, there is more pollen in the air on warm, bright, sunny, breezy days, hence the symptoms are intensified; various species of plants disperse pollen only during certain periods, hence the periodicity and abrupt termination of the hay fever seasons.

Pollen may be defined as the fine, dust-like, powdery (occasionally coherent) material developed within the anthers of flowers of seed-bearing plants. This material, which to the unaided vision appears like so much colored powder, is composed of separate particles called pollen grains. In the entire plant kingdom there are about 133,000 different species of plants which produce pollen. Hence, there are that many potential causes of hay fever. To be a cause of hay fever, however, a species of pollen must satisfy each of five requirements. Fortunately very few species of pollen satisfy these requirements, which are:

1. *The pollen must contain a chemical substance capable of producing the symptoms.* The nature of this substance has not been definitely established. It is probably the albuminous protein, or a substance closely associated with it. The excitant of hay fever, found in pollen, is among the most powerful of all known bio-chemical substances. A reaction in the skin of a sensitive person can be obtained with the amount of excitant contained in 1/5,500,000 of a grain by

weight, of ragweed pollen. (A grain by weight of ragwed pollen is about 1/40 of a level teaspoonful).

2. *The pollen must be anemophilous or wind-borne as regards the mode of pollination.*

By pollination is meant the transference of pollen from the anther to the stigma of the pistil. There are several types of pollination.

a. *Close Pollination,* in which pollen is deposited on the stigma of the same flower that bears the pollen. In some plants this occurs without the opening of the flower; this is termed cleistogamy. Examples are several species of violets (*Viola palmata, V. triloba*), henbit (*Lamium amplexicaule*), and wood sorrel (*Oxalis Acetosella*).

b. *Water Pollination,* which occurs in flowers that dwell within the waters of lakes, streams, etc. The pollen is conveyed by the water to the stigma. Tassel pondweed, (*Ruppia*), eel-grass (*Zostera*), and water-weed (*Elodea*) are examples.

c. *Insect Pollination,* in which the pollen grains are conveyed from anther to stigma by insects. Such flowers are termed *entomophilous,* and are as a rule large, attractively colored, and supplied with scent and nectar-producing glands. When the flowers are individually small they are frequently grouped in such a manner as to attain conspicuousness, as in many of the composites (e.g. dahlias, daisies, goldenrods, galinsogas), rhododendrons, elderberries (*Sambucus*) and other plants. In other instances, showy appendages cause the flower to be conspicuous, as in the dogwood (*Cornus florida*). Entomophilous pollen occurs in compact masses called *pollinia* (orchids and milkweeds); in indefinite masses due to the effect of a sticky, stringy, structureless substance called viscin (Fuschias, godetias, azaleas, etc.), and in powdery masses.

d. *Wind Pollination,* in which the pollen is conveyed from anther to stigma through the agency of the wind. Such flowers are called *anemophilous,* and are not showy, attractive, or provided with nectar glands; they are reduced in size, and rarely have any scent; in a word they are inconspicuous.

It is obvious that the pollen of only wind pollinated plants could cause hay fever, because it is only such pollen that finds its way into the atmosphere. Insect pollinated plants may occasionally cause hay fever in sensitive persons (1) by the deliberate smelling of such blossoms, (2) by exposure to an abundant growth, as when the plants are profusely grown in the patient's accustomed environment, and (3) when used to any extent for decorative purposes within the house or business quarters.

3. *The pollen must be produced in sufficiently large quantities.* An outstanding characteristic of the pollen of wind pollinated plants is its frequent production in large quantities. A single well developed specimen of short ragweed (*Ambrosia artemisiifolia*), which bore 5006 flower clusters, was calculated to be capable of giving off approximately one million million pollen grains. An average large bush (3 ft. 10 in. high) of the bastard feverfew (*Parthenium hysterophorus*) gave off about 227,000,000 pollen grains per day. A specimen of giant ragweed (*Ambrosia trifida*) shed about 8 billion pollen grains in 5 hours and a field of grass (*Paspalum dilatatum*) was estimated to have yielded 8 million pollen grains per square foot of surface, during the active stage of pollination. It has been esti-

mated that an average city lot (about one-tenth acre) of ragweeds can produce 100 ounces—that is, about 60 pounds per acre. In a city like Chicago, for example, there are enough weedy lots to produce several hundred tons of ragweed pollen each season. The giant ragweed plants collected from an area 20 feet by 20 feet (400 sq. feet), yielded 200 grams of pollen (more than a pint in volume) in 3 days. The significance of these figures is readily appreciated when one bears in mind that the individual pollen grain of ragweed is so minute that there are about 380,000,000 in 1 gram (about 1/3 of a level teaspoonful).

From data obtained by studying the pollen content of the air, it is estimated that in the atmosphere of Greater New York there are, at the height of the ragweed season, about 25,000 billions of pollen grains—and the hay fever subject needs only 4 or 5 pollen grains to induce a severe fit of sneezing.

In wind pollinated plants it is because of the rather haphazard method of pollination that Nature produces such a superabundance of pollen. In contrast to this abundance of production, the flowers of insect pollinated plants produce comparatively small yields of pollen. It has been computed that an entire dandelion flower produces only 243,000 pollen grains; a peony 3,645,000, and an entire rhododendron plant only 72,620,000 grains.

4. *The pollen must be sufficiently buoyant to be carried considerable distances.* Another characteristic of the pollen of wind-pollinated plants is its buoyancy, which, however, varies considerably with the different species. Pine pollen is exceptionally buoyant. It is recorded that after a thunderstorm in mid-March, 1873, the ground of a certain section of St. Louis, Mo., was sufficiently covered with pollen to appear as though sprinkled with sulphur. This pollen, it was thought, belonged to a certain species of pine then in bloom in the southern states, whence it was carried by the wind—a distance of 400 miles. In 1918 a Swedish investigator exposed glass plates on two lightships, anchored in the Gulf of Bothnia, 18.6 miles and 34.1 miles, respectively, from land. These glass plates were covered with a thin layer of vaseline which served to "catch" any pollen grains carried by the wind. On the nearer lightship, 395 pollen grains per sq. millimeter per day fell from May 16 to June 26. On the farther lightship the figure was 215. The total number of pollen grains of the several trees counted on the prepared glass plates on the first and second lightships, respectively, during this 41 day period was: spruce, 44,265 and 26,000; pine, 15,194 and 6,800; birch, 43,306 and 23,200; others, 272 and 75.

On June 17, 1866, an English investigator studied the pollen content of the upper strata of the air by attaching prepared pieces of glass to kites which he flew single and in tandem, reaching a height of 1,000 and 1,500 feet respectively. He observed that while the average count at ordinary levels was 24 grass pollen grains per plate, that for high altitudes was 472.33—that is, 19 times the quantity was present in the upper strata as compared with the lower. This

emphasizes the great buoyancy of grass pollen and the effect of the upward-travelling air currents. Similar studies were made in America fifty years later, with the aid of the airplane. It was thereby ascertained that ragweed pollen reached a height of at least 12,000 feet, and grass pollen was found as high as 17,000 feet (more than 3 miles). In many of these tests the number of pollen grains of both grass and ragweed collected at altitudes varying from 4,000 to 6,000 feet was greater than that found near the surface. In Germany, in 1925, a series of similar experiments was made. The existence of pollen in the upper strata of the air and its gradual descent due to descending air currents, explains the frequent aggravation of hay fever symptoms after sunset and during the prevalence of cold winds—such aggravation being otherwise inexplicable, for it is definitely established that the ragweeds and many of the grasses disperse their pollen mainly from about sunrise to 10 a. m.

An important factor determining the buoyancy of pollen is the size of the individual grains. The unit of measure of microscopic objects in general is the *micron,* which is practically 1/25,000 of an inch, and which is represented by the Greek letter μ (mu).

There are pollen grains so small that they measure only 2.5 μ in diameter (e. g. the forget-me-not, *Myosotis alpestris*) and others which are gigantic in comparison, for example, the Marvel of Peru (*Mirabilis Jalapa*), which is 250 μ. If it be remembered that the volumes of solids are proportional to the cubes of their diameters it is evident that the larger of these grains is a million times greater in volume than the smaller, and therefore a million times heavier, assuming that their specific weights are the same.

The majority of pollens which are important causes of hay fever are less than 40 μ in size. The importance of the size of the pollen grain in its relation to hay fever is exemplified in the case of corn pollen. The pollen of corn is capable of causing severe symptoms in susceptible individuals when used experimentally. Though widely grown, its pollen is not, however, an important factor, because it is too large to be sufficiently buoyant, being about 90 μ in diameter. Ragweed pollen is about 15 μ in diameter, and is exceedingly buoyant, being easily carried 10 miles in a moderate wind. The pollen grain of corn is 216 times greater in volume and probably that many times greater in weight than ragweed pollen. Hence it causes symptoms in susceptible individuals only when they are in proximity to cornfields. Hay fever caused by ragweed pollen, however, occurs in susceptible persons even when they live in the centers of great cities far removed from vegetation.

5. *The plant producing the pollen must be widely and abundantly distributed.* The significance of this requirement is best realized by considering the fact that nearly every important hay fever-causing plant is found represented in the flora of New York State; yet the number actually causing hay fever in this section is definitely limited to several genera of trees in the spring, several grasses in the late spring and summer, and the ragweeds in the late summer and

fall. The artemisias (wormwoods), are the most important causes of hay fever in the western states; yet House, in his *Annotated List of the Ferns and Flowering Plants of New York State,* mentions 18 different species of artemisias, and Taylor in the *Flora of the Vicinity of New York City* (i. e., within 100 miles of the metropolis) reports the occurrence of 7 species. Bermuda grass (*Capriola Dactylon*), the principal hay fever grass of the southern and western states, is also found in this area; and so too are the Russian thistle (*Salsola pestifer*), several water hemps (*Acnida*), 9 amaranths, 17 goosefoots (*Chenopodium*), 8 species of *Atriplex,* and 14 species of dock (*Rumex*). These are all hay fever-causing species, yet they do not cause hay fever in New York, because they fail to satisfy this fifth requirement.

Goldenrod is erroneously thought to cause hay fever. It produces an active pollen in fair abundance, and there are about 50 species in northeastern North America, the growth of which is frequently so luxuriant that in many sections the landscape is colored a golden yellow by their blooms. It is not a cause of hay fever, however, because very little of its pollen gets into the air, since it is insect pollinated and, moreover, the pollen lacks buoyancy because of its sticky character.

Summary. Fortunately, very few plants satisfy these requirements adequately. In northeastern North America, north of Tennessee and North Carolina and east of the western border of Kansas, there have been described 4,045 species of flowering plants. Of these approximately 1,040 are wind-pollinated. Of these latter only the following satisfy all of the requirements:

Trees (causing hay fever during periods from March to June): maples, elms, poplars, birches, beech, ashes, oaks, walnuts, and hickories. A person may be affected by the pollen of one or more than one genus of trees. When sensitive to one species of pollen, a patient will be sensitive to the pollen of all the species of that genus; if hay fever is caused by one kind of oak pollen, all oak pollens will produce symptoms.

Grasses. Of the 1500 different species of grasses recorded in the United States, likewise only a few cause hay fever. Within a hundred-mile radius of New York City about 270 different species have been found, and there is no time from early spring until autumn when some species is not in bloom. However, only a small number cause hay fever, and only from the end of May to mid-July.

There are only 3 grasses of primary importance. 1. Timothy (*Phleum pratense*), 2. June grass (*Poa pratensis*), and 3. Bermuda grass (*Capriola Dactylon*), the last occurring in the southern and western states. If these three grasses were entirely eliminated from the country's flora, hay fever caused by grass pollen would be reduced more than 90 per cent.

The grasses of decidedly secondary importance are orchard grass (*Dactylis glomerata*), Johnson grass (*Holcus halepensis*), couch grass (*Agropyron repens*), and sweet vernal grass (*Anthoxanthum

odoratum). If a person is sensitive to one grass pollen, he will be found sensitive to probably all grass pollens in greater or less degree, for it appears that the capacity to produce hay fever is a characteristic of the grass family.

Weeds. In the northeastern quarter of the United States, the most important weeds causing hay fever are the low and the giant ragweeds. They disperse their pollen from about mid-August until October 1st. In the western states, the wormwoods take the place of the ragweeds in importance. If the ragweeds and the wormwoods were eliminated from our flora, probably 90 per cent of the hay fever caused by weeds could not occur.

Other weeds of secondary importance, causing hay fever in various sections of the country are: the Gaertnerias, the Ivas, the Xanthiums, the pigweeds (Amaranths), the goosefoots (Chenopods), the Acnidas, the Atriplexes, Russian thistle, the docks (Rumex), hemp, hop, and English plantain.

The mechanism of hay fever. If in a given section of the country, everyone breathes the same pollen-bearing atmosphere, why do not all have hay fever? Because there are three requisites necessary for the production of hay fever: 1, pollen; 2, the presence of certain sensitizing substances in the blood, called *reagins;* and 3, the presence of a peculiarity in certain tissues, the mucous membranes of the eyes, nose, etc., which causes them to respond to the irritating effects of the pollen. Unless these three requisites are present, hay fever symptoms do not occur. Reagins are specific, that is, a given reagin responds to the chemical substances present only in certain pollens and not in others. If a person has ragweed hay fever, the reagins in his blood respond only to ragweed pollen; if he has both ragweed and grass hay fever, his blood will contain both reagins. The specific character of the reagins explains why it is that one person has hay fever in June and July, and another one in August and September. The most important factor determining the capacity of an individual to form reagins is heredity.

Diagnosis. How does one know he has hay fever? The occurrence of a spring or summer "cold", having a number of the characteristics, symptoms, and signs already mentioned (pages 1 and 2) is presumptive evidence that it is not an ordinary "cold". The specially trained physician accurately establishes the diagnosis by making skin tests, that is, by injecting into the uppermost layer of the skin small quantities of the specially prepared watery extracts of various pollens. A positive reaction results when an irregular swelling occurs at the site of the test several times the size of the original wheal produced by the test injection. In this manner, the particular pollens causing the individual's hay fever are determined.

Fallacies concerning Hay Fever. Hay fever is a much-talked-about disease, therefore it is not surprising that there are a number of fallacies and misconceptions generally held concerning it.

The following are the most important fallacies and misconceptions concerning hay fever:

1. That hay fever is contagious.
2. That goldenrod causes hay fever.
3. That there is such an ailment as "rose cold".
4. That hay fever occurs chiefly in so-called nervous people.
5. That hay fever is a disease of the eyes and nose.
6. That hay fever is a trivial matter.
7. That hay fever is spontaneously cured at the seventh year.
8. That hay fever is contracted as a result of the patient's having lived in, or visited a certain place.
9. That hay fever occurs most often in well-educated and intelligent people, and that it shows a special predilection for the so-called upper classes of society.
10. That diet is a factor in the causation of hay fever, and that it materially influences the symptoms.
11. That hay fever returns on the same day each year.
12. That hay fever is caused by an individual's proximity to *any* weeds, grasses or trees during their flowering periods.
13. That all persons are equally susceptible to hay fever.
14. That hay fever cannot be cured.
15. That a fixed number of pollen extract injections constitutes an adequate treatment of hay fever.
16. That hay fever can be cured by a nasal operation.
17. That the term hay fever is an accurate one.

The treatment of Hay Fever. For almost 100 years after it was first described by Bostock (1819), medical science had no satisfactory method for treating the malady. Numerous indeed were the measures advocated, often quite enthusiastically, but none proved at all effectual. These measures ranged from the use of eye-drops, nasal sprays, special eyeglasses, special clothing, etc., to extensive operations on the nose. In 1911, Noon, an Englishman, began to treat hay fever subjects with watery extracts of pollen. At Noon's untimely death, his original work was carried on by a colleague, J. Freeman. The method of treating hay fever inaugurated by these English doctors has been improved and perfected, through the investigations and experiments of many medical scientists in various parts of the world. It is the only method of treating hay fever which has stood the test of time. By it a condition termed *hyposensitization* (reduced sensitiveness) is produced by a series of injections (given underneath the skin) of increasing doses of liquid extracts of pollen. In the hands of the specially trained physician, this method of treating hay fever has proved highly efficacious. It is the only effective method of preventing the asthmatic complications.

Various palliative measures are also in use; eye drops, nasal sprays, air filtration, the temporary sojourn in sections where the offending plants do not grow, and ocean travel, but these are not cures.

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